

APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

**A Wireless Apparatus
Having A Transceiver Equipped
To Support Multiple Wireless Communication Protocols**

Inventor(s): **Ephraim Zehavi
Ron Nevo**

Prepared by:

BLAKELY SOKOLOFF TAYLOR & ZAFMAN, LLP
12400 Wilshire Boulevard, 7th Floor
Los Angeles, California 90025
(503) 684-6200

"Express Mail" label number EL034433368US

Date of Deposit November 8, 1999

A Wireless Apparatus Having A Transceiver
Equipped To Support Multiple Wireless Communication Protocols

BACKGROUND OF THE INVENTION

5

1. **Field of the Invention**

The present invention relates to the field of wireless communication. More specifically, the present invention relates to the problem of concurrent wireless communication with multiple communication partners subscribing to different wireless communication protocols.

10

2. **Background Information**

Advances in microprocessor and communication technology have led to the increase in popularity of wireless communication. Once confined to the privileged, wireless voice communication have become affordable and available to the masses. Today, various efforts are under way to apply wireless communication to replace attachment cables used for attaching peripheral devices, such as printers, scanners and the like, as well as networking cables used for connecting clients, servers and the like. A leading candidate to accomplish the former is commonly known to those skilled in the art as the Bluetooth technology or Bluetooth protocol. Examples of technology to accomplish the later include the different variants of the IEEE 802.11 Standard published by the Institute of Electrical and Electronic Engineers, 802.11 (Frequency Hopping and Direct Sequence), 802.11a, 802.11b as well as Home RF, also known as Shared Wireless Access Protocol (SWAP) to those skilled in the art.

15

20

25

A need has emerged in a number of applications that it is desirable for a device to be able to operate "concurrently" in multiple wireless protocols. One such

applications is having a notebook computer being able to communicate with peripheral devices such as a phone, a printer, a scanner and the like, in accordance with the Bluetooth protocol; and with other computing devices, such as other peer computers or servers, communication devices, such as modems or adapters, and
5 networking devices, such as gateways, routers, switches and the like, in accordance with one of the 802.11 protocols or Home RF.

However, the need cannot be met by simply providing the device with multiple transmitters, one for each protocol. The reason is because if multiple ones of these transmitters were to transmit at the same time. The transmitters are going
10 to interfere with each other, resulting in corruption and/or loss of data, as well as degradation in performance.

As will be described in more detail below, the present invention substantially address this need in a very efficient and low cost manner. This and other advantages of the present invention will be readily apparent from the description to
15 follow.

SUMMARY OF THE INVENTION

A wireless device is provided with a wireless transceiver having a joint signal transmit/receive section to transmit and receive signals wirelessly in accordance
5 with a first and a second protocol. In one embodiment, the wireless device is further provided with a first and second up/down conversion pair to correspondingly up and down convert the transmit and receive signals in accordance with the two protocols. In an alternate embodiment, the wireless device is provided with a first and second down conversion unit to correspondingly down convert the receive signals, and a
10 shared up conversion section to up convert transmit signals, in accordance with the two protocols. In either case, the wireless device is further provided with a controller/signal processing section to control and perform, in a coordinated manner, the transmit and receive operations in accordance with the two protocols.

In various embodiments, the wireless device is further provided with a
15 processor programmed to implement a time sharing schedule to facilitate the coordinated control and performance of the transmit and receive operations. In some of these embodiments, the processor is further programmed to monitor the transmit and receive workloads of the two protocols and adaptively perform the coordinated control and signal processing, based at least in part on the observed
20 workloads.

In various embodiments, the protocols may be selected pairs of Bluetooth, 802.11, 802.11a, 802.11b, Home RF and the like. The wireless device may also be used as a master device or a gateway device of two wireless networks.

BRIEF DESCRIPTION OF DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references
5 denote similar elements, and in which:

Figure 1 illustrates an overview of the wireless device of the present invention, in accordance with one embodiment;

Figure 2 illustrates a period of operation of the wireless device of the present invention, in accordance with one embodiment;

10 **Figure 3** illustrates the transceiver of the wireless device of **Fig. 1** in further detail, in accordance with one implementation;

Figure 4 illustrates the signal processing subsection of controller/signal processing section of the wireless device of **Fig. 1** in further detail, in accordance with one implementation;

15 **Figures 5a-5c** illustrate the controller subsection of the controller/signal processing section of **Fig. 1** in further detail, in accordance with one implementation;

Figure 6 illustrates an overview of the present invention, in accordance with another embodiment;

20 **Figure 7** illustrates the transceiver of the wireless device of **Fig. 6** in further detail, in accordance with one implementation; and

Figure 8 illustrates the controller subsection of the controller/signal processing section of **Fig. 6** in further detail, in accordance with one implementation.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, various aspects of the present invention will be described. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some or all aspects of the present invention. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the present invention. However, it will also be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well known features are omitted or simplified in order not to obscure the present invention.

Parts of the description will be presented using software terminology commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. As well understood by those skilled in the art, these software quantities take the form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, and otherwise manipulated through mechanical and electrical components of a digital system; and the term digital system includes general purpose as well as special purpose processors, systems, and the like, that are standalone, adjunct or embedded.

Various operations will be described as multiple discrete steps performed in turn in a manner that is most helpful in understanding the present invention, however, the order of description should not be construed as to imply that these operations are necessarily order dependent, in particular, the order the steps are presented. Furthermore, the phrase "in one embodiment" will be used repeatedly, however the phrase does not necessarily refer to the same embodiment, although it may.

Referring now to **Figure 1**, wherein an overview of the present invention in accordance with one embodiment is shown. As illustrated, wireless device **100** is provided with wireless transceiver **102** of the present invention to transmit and receive signals wirelessly in accordance with a first and a second wireless communication protocol, in a coordinated manner, to enable device **100** to communicate with devices **104a** and devices **104b** of wireless networks **108a** and **108b**, at substantially the same time. Wireless transceiver **102** includes joint signal transmit/receive section **103**, and for the illustrated embodiment, a first and a second signal up/down conversion pairs **105a-105b** sharing joint signal transmit/receive section **103**. Wireless device **100** further includes controller/signal processing (C/SP) section **106** to process data for transmission by wireless transceiver **102**, to process signals received by wireless transceiver **102**, and to control the data/signal processing operations as well as the operation of wireless transceiver **102**.

In one embodiment, C/SP section **106** controls the data/signal processing operations and wireless transceiver **102** (hereinafter, simply transceiver), in a synchronized and coordinated fashion. More specifically, in this embodiment, C/SP section **106** controls the data/signal processing operations and transceiver **102** to alternate between transmits in a selected one of the two wireless communication protocols, and receives in both protocols. **Figure 2** illustrates a period of operation in accordance with this embodiment. As shown, in time period T1, for duration t1, C/SP section **106** operates joint signal transmit/receive section **103** and signal up/down conversion pairs **105a-105b** to perform transmit of signals to devices **104a** of wireless network **108a** (hereinafter, simply network) in accordance with the first wireless communication protocol (hereinafter, simply protocol), at the exclusion of devices **104b** of network **108b**. During this period, C/SP section **106** also

temporarily suspends processing of signals output from the signal down conversion sections of signal up/down conversion pairs **105a-105b**. In time period T3, for duration t3, the operation is performed for the second protocol. That is, C/SP section **106** operates joint signal transmit/receive section **103** and signal up/down conversion pairs **105a-105b** to perform transmit of signals to devices **104b** of network **108b** in accordance with the second protocol, at the exclusion of devices **104a** of network **108a**; and in like manner, temporarily suspends processing of signals output from the signal down conversion sections of signal up/down conversion pairs **105a-105b**. In time periods T2 and T4, for duration t2 and t4 respectively, C/SP section **106** processes signals output by the down conversion sections of both signal up/down conversion pairs **105a-105b** to receive signals from devices **104a** and **104b** of networks **108a** and **108b** in accordance with the respective protocols. During these time periods, C/SP section **106** temporarily suspends transmissions of signals to devices **104a** as well as devices **104b** of networks **108a** and **108b**.

Since all wireless protocols operate on either a carrier sense or contention free protocol, devices **104a** are able to receive in time period T1, and transmit when there are packets to transmit, but otherwise receive, in time periods T2-T4.

Likewise, devices **104b** are able to receive in time period T3, and transmit when there are packets to transmit, but otherwise receive, in time periods T1-T2 and T4.

Accordingly, wireless device **100** is able to operate with devices **104a** and **104b** of networks **108a** and **108b** in two wireless protocols at the same time.

Note that time periods T1-T4 may or may not be equal in duration. That is, numerically t1-t4 may or may not be equal. As will be described in more detail below, in different variants of this embodiment, duration t1-t4 of time periods T1-T4 are dynamically and adaptively set. In particular, in some variants, duration t1-t4 of

time periods T1-T4 are adaptively set based at least in part of transmit and receive workloads of networks **108a** and **108b**.

Referring back to **Fig. 1**, except for the teachings of the present invention incorporated in wireless device **100** to effectuate the above described coordinated manner of operation of C/SP section **106**, joint signal transmit/receive section **103** and signal up/down conversion pairs **105a-105b** of transceiver **102**, C/SP section **106**, joint signal transmit/receive section **103** and signal up/down conversion pairs **105a-105b** of transceiver **102** are otherwise intended to represent a broad range of these elements known in the art. Accordingly, except for the teachings of the present invention, which will be further described below, transceiver **102** and C/SP section **106** will not be otherwise further described.

Wireless device **100** is intended to represent a wide range of devices that can benefit from having the ability to wirelessly operate with other wireless devices in two or more wireless communication protocols at the same time. Examples of device **100** include but not limited to computers of various form factors, such as desktop, notebook, palm size and so forth, controller devices (i.e. master devices) to manage and control the operation of networks **108a** and **108b**, and gateway devices to facilitate communication between devices **104a** and devices **104b**.

Likewise, devices **104a** and **104b** are intended to represent a broad range of devices that can benefit from being able to communicate wirelessly. Examples of devices **104a** include but not limited to phones, video cameras, speakers, modems, printers and scanners equipped to wireless communicate in accordance with the Bluetooth protocol. Examples of devices **104b** include clients and servers, as well as gateways, modems, hubs, routers, and switches equipped to wireless communicate in accordance with a selected variant of the IEEE 802.11 protocols or Home RF. In these example embodiments, joint signal transmit/receive section **103**

is a joint RF transmit/receive section, and each signal up/down conversion pair **105a/105b** is an IF up/down conversion pair.

For ease of understanding, only two groups of devices **104a** and **104b** communicating in accordance with the first and second wireless communication protocols (supported by two up/down conversion sections **105a-105b** in transceiver **102**) are shown in **Fig. 1**. However, from the description to follow, it will be readily apparent to those skilled in the art, the present invention may be practiced with more than two protocols, with employment of additional signal up/down conversion sections for the additional protocols, as long as they are likewise coordinated.

Referring now to **Figure 3**, wherein transceiver **102** is illustrated in further detail, in accordance with one implementation. As described earlier, transceiver **102** includes joint signal transmit/receive section **103**, and first and second signal up/down conversion pairs **105a-105b** sharing joint signal transmit/receive section **103**. As illustrated and alluded to earlier, joint signal transmit/receive section **103** is similarly constituted as prior art transmit/receive sections, with switch **302**, low noise amplifier (LNA) **304**, power amplifier (PA) **306** and filters **308a-308b** coupled to each other as shown. The functions and constitutions of these elements are known in the art. Each signal up/down conversion section **105a/105b** is also similarly constituted as in the prior art, with a signal up conversion subsection **316a/316b** and a signal down conversion subsection **314a/314b** for up and down conversion of signals of different frequencies of interest. Similarly, the functions and constitutions of these up and down conversion subsections are also known in the art. In one embodiment, joint transmit/receive section **103** is the earlier mentioned joint RF transmit/receive section that operates in a radio frequency, whereas first and second signal up/down

conversion pairs **105a/105b** are the earlier mentioned IF up/down conversion pairs that operate in intermediate frequencies.

In accordance with the present invention, down conversion subsections **314a-314b** of up/down conversion pairs **105a-105b** are coupled to joint signal

5 transmit/receive section **103** in parallel, via splitter **310**. That is, receive signals output by filter **308a** are provided to both down conversion subsections **314a-314b** for down conversions in their respective frequencies of interest, allowing receive signals transmitted in different frequencies or protocols to be received at the same time. In the case of up conversion subsections **316a-316b** of up/down conversion pairs **105a-105b**, they are selectively coupled to joint signal transmit/receive section **103**, via switch **312**. That is, transmit signals from up conversion subsections **314a-314b** operating in their respective frequencies are selectively provided to filter **308b** to filter, in preparation for transmission, at the exclusion of the other, resulting in only signals from one frequency of interest (or protocol) being transmitted at any one

10

15 point in time.

Referring now to **Figure 4**, wherein the signal processing subsection of C/SP section **106** is illustrated in further detail, in accordance with one implementation.

As illustrated, signal processing subsection **402** of C/SP section **106** includes

20 memory **402**, first and second receive signal processing blocks **404a-404b** for first and second protocols, first and second transmit data processing blocks **406a-406b** for first and second protocols, and A/D as well as D/A converters **408a-408b** and **410a-410b**. These elements perform their conventional functions known in the art, and their constitutions are protocol dependent, that is depending on the protocol

25 they are designed/configured to support, e.g. an 802.11 variant or Bluetooth and so forth. A/D and D/A converters **408a-408b** and **410a-410b** convert analog signals

into digital signals, and digital signals to analog signals respectively. First and second receive signal processing blocks **404a-404b** process the digitized receive signals in accordance with their respective protocols to extract receive data, and store the extracted receive data in memory **402**. First and second transmit data processing blocks **406a-406b** process transmit data stored in memory **402** and package them for conversion and then transmission in accordance with first and second protocols respectively (e.g. adding headers, check sums and so forth). Except for the manner they are advantageously used to effectuate the substantially simultaneous communication with wireless devices in two protocols, these elements are otherwise known in the art. In one embodiment, receive and transmit signal processing blocks **404a** and **406a** process receive signals and package transmit data in accordance with a selected one of IEEE 802.11, 802.11a and 802.11b, and the Home RF protocol, whereas receive and transmit signal processing blocks **404b** and **406b** process receive signals and package transmit data in accordance with the Bluetooth protocol.

In an alternate embodiment, support for a selected one of IEEE 802.11, 802.11a and 802.11b, and the Home RF protocol may be dynamically selected. In this embodiment, multiple ones of receive and transmit signal processing blocks **404a** and **406a** are provided, and coupled to A/D and D/A converters **408a** and **410a** via a switching matrix.

Referring now to **Figures 5a-5c**, wherein controller subsection **500** of C/SP section **106** is illustrated in further detail, in accordance with one implementation. As illustrated in **Fig. 5a**, controller subsection **500** includes processor **502** and memory **504**. Stored in memory **504** are programming instructions **506** to be executed by processor **502** to effectuate the earlier describe control of the receive

and transmit processing operations of the signal processing subsection of C/SP section **106** and transceiver **102** for the time sharing mode of operation as set forth referencing **Fig. 2**.

As illustrated in **Fig. 5b**, at **512**, processor **502** (executing programming instructions **506**) causes signal up conversion subsection **314a** of first signal up/down conversion pair **105a** to be coupled to joint signal transmit/receive section **103** at the exclusion of signal up conversion subsection **314b** of first signal up/down conversion pair **105b**. At the same time, processor **502** causes receive signal processing blocks **404a** and **404b** to temporarily ignore or suspend processing signals output by down conversion subsections **314a-314b**. At **514**, processor **502** repeatedly determines if it has operated in this mode for a sufficient duration, i.e. if elapsed time for period T1 has reached t1. Eventually, upon determining it has operated in this mode for the appropriate duration, the process continues at **516**.

At **516**, processor **502** causes signal up conversion subsections **314a-314b** of both first and second signal up/down conversion pairs **105a-105b** to be decoupled from joint signal transmit/receive section **103**, thereby preventing signals to be transmitted under either protocol. Furthermore, processor **502** causes receive signal processing blocks **404a** and **404b** to resume processing signals output by down conversion subsections **314a-314b**, thereby allowing signals received in both protocols to be processed and received at the same time. At **518**, processor **502** repeatedly determines if it has operated in this mode for a sufficient duration, i.e. if elapsed time for period T2 has reached t2. Eventually, upon determining it has operated in this mode for the appropriate duration, the process continues at **520**.

At **520**, processor **502** causes signal up conversion subsection **314b** of second signal up/down conversion pair **105b** to be coupled to joint signal transmit/receive section **103** at the exclusion of signal up conversion subsection

314a of first signal up/down conversion pair 105a. At the same time, processor 502 causes receive signal processing blocks 404a and 404b to temporarily ignore or suspend processing signals output by down conversion subsections 314a-314b. At 522, processor 502 repeatedly determines if it has operated in this mode for a sufficient duration, i.e. if elapsed time for period T3 has reached t3. Eventually, upon determining it has operated in this mode for the appropriate duration, the process continues at 524 and 526.

At 524 and 526 processor performs the same functions as earlier described for 516 and 518. Eventually, upon determining it has operated in this mode for period T4 for time t4, the process continues at 512.

Referring back to Fig. 5a, for the illustrated embodiment, memory 504 is also used to store the duration values t1-t4, allowing the length of periods T1-T4 to be programmable. Furthermore, as described in below and illustrated in Fig. 5c, programming instructions 506 are also equipped to adaptively adjusted these values. Referring now to Fig. 5c, at 532-534, processor monitors for transmit and receive packets of each protocol, and upon detection, updates two workload counters, one for each of the protocols, accordingly. At 536, processor determines if the period for monitoring has elapsed. The period may be pre-programmed or provided through e.g. a programmable configuration register (not shown).

Operations 532-534 are repeated until the monitoring period has expired. At such time, the process continues at 538, where processor 502 analyzes the cumulated workload data for the two protocols, and adaptively adjusted the duration values t1-t4 for periods T1-T4, based at least in part on the observed workloads for the two protocols. The adjustment may be made in a straight forward proportional manner, or employing any one of a number of heuristic approaches.

Upon making the adjustment, in one embodiment, processor **502** resumes the monitoring immediately. In an alternate embodiment, processor **502** resumes the monitoring after waiting a pre-determined or dynamically determined period of time. Alternatively, it may also resume only upon invoked to do so.

5

Referring now to **Figure 6**, wherein an overview of the present invention in accordance with an alterante embodiment is shown. As illustrated, similar to the embodiment earlier described referencing **Fig. 1**, wireless device **100'** is provided with wireless transceiver **102'** of the present invention to transmit and receive signals wirelessly in accordance with a first and a second wireless communication protocol, in a coordinated manner, to enable device **100'** to communicate with devices **104a** and devices **104b** of wireless networks **108a** and **108b**, at substantially the same time. Similar to the embodiment of **Fig. 1**, wireless transceiver **102'** includes joint signal transmit/receive section **103**. However, unlike the embodiment of **Fig. 1**, wireless device **100'** is provided with a first and a second signal down conversion section **105c-105d** and a common signal up conversion unit **105e**, sharing joint signal transmit/receive section **103**. Wireless device **100'**, as the embodiment of **Fig. 1**, further includes controller/signal processing (C/SP) section **106** to process data for transmission by wireless transceiver **102'**, to process signals received by wireless transceiver **102'**, and to control the data/signal processing operations as well as the operation of wireless transceiver **102'**. In one embodiment, C/SP section **106** controls the data/signal processing operations and wireless transceiver **102'**, in a synchronized and coordinated fashion, as described earlier.

Figure 7 illustrates transceiver **102'** in further detail, in accordance with one implementation. Joint signal transmit/receive section **103** is similarly constituted as

earlier described. Each signal down conversion section **105c/105d** is also similarly constituted as in the prior art, and functions as earlier described signal down conversion subsection **314a/314b**. Common signal up conversion section **105e** serves the functions of both signal up conversion subsections **316a** and **316b**.

5 As earlier described, down conversion sections **105c-105d** are coupled to joint signal transmit/receive section **103** in parallel, via splitter **310**. That is, receive signals output by filter **308a** are provided to both down conversion sections **105c-105d** for down conversions in their respective frequencies of interest, allowing receive signals transmitted in different frequencies or protocols to be received at the same time. In the case of common up conversion sections **105e**, it is selectively coupled to the transmit signal processing sections of C/SP **106**, via switch **312**. That is, transmit signals of the two protocols are provided to filter **308b** through up conversion section **105e** operating in one of two frequencies, at the exclusion of the other, for preparation for transmission, resulting in only signals from one frequency of interest (or protocol) being transmitted at any one point in time.

C/SP **106** is similarly constituted as earlier described referencing **Fig. 4**, including controller subsection **500**, which is constituted as earlier described referencing **Fig. 5a**. However, the operational flow of controller subsection **500** under this alternate embodiment is slightly different, which is illustrated in **Fig. 8**.

20 At **812**, processor **502** (executing programming instructions **506**) causes signal up conversion section **105e** to be coupled to transmit signal processing subsection **406b** of signal processing section **400** (for the first protocol), at the exclusion of transmit signal processing subsection **406a** (for the second protocol). At the same time, processor **502** causes receive signal processing blocks **404a** and 25 **404b** to temporarily ignore or suspend processing signals output by down conversion subsections **105c-105d**. At **814**, processor **502** repeatedly determines if

it has operated in this mode for a sufficient duration, i.e. if elapsed time for period T1 has reached t1. Eventually, upon determining it has operated in this mode for the appropriate duration, the process continues at **816**.

At **816**, processor **502** causes signal up conversion section **105e** to be de-
 5 coupled from both transmit signal processing subsections **406a** and **406b** of signal processing section **400**, thereby preventing signals to be transmitted under either protocol. Furthermore, processor **502** causes receive signal processing blocks **404a** and **404b** to resume processing signals output by down conversion sections **105c-105d**, thereby allowing signals received in both protocols to be processed and
 10 received at the same time. At **818**, processor **502** repeatedly determines if it has operated in this mode for a sufficient duration, i.e. if elapsed time for period T2 has reached t2. Eventually, upon determining it has operated in this mode for the appropriate duration, the process continues at **820**.

At **820**, processor **502** causes signal up conversion section **105e** to be
 15 coupled to transmit signal processing subsection **406a** of signal processing section **400** (for the second protocol), at the exclusion of transmit signal processing subsection **406b** (for the first protocol). At the same time, processor **502** causes receive signal processing blocks **404a** and **404b** to temporarily ignore or suspend processing signals output by down conversion sections **105c-105d**. At **822**,
 20 processor **502** repeatedly determines if it has operated in this mode for a sufficient duration, i.e. if elapsed time for period T3 has reached t3. Eventually, upon determining it has operated in this mode for the appropriate duration, the process continues at **824** and **826**.

At **824** and **826** processor performs the same functions as earlier described
 25 for **816** and **818**. Eventually, upon determining it has operated in this mode for period T4 for time t4, the process continues at **812**.

Thus, a wireless device equipped to substantially operate currently with multiple wireless communication protocols has been described. While the present invention has been described in terms of the above illustrated embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described. The present invention can be practiced with modification and alteration within the spirit and scope of the appended claims. The description is thus to be regarded as illustrative instead of restrictive on the present invention.